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Active Control of Long Suspension Bridges

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Abstract

Along with the apperance of still more sophisticated structural analysis methods there has been a tendency to build more slender and flexible civil engineering structures. In return of these material savings, structures has become highly sensible to vibrations from dynamic loadings. Because this problem has become actual, further material savings will rely on whether the structures can be equipped with damping devices, which reduces the vibration to an acceptable level.

The present abstract deals with the application of a active closed-loop control system for the limitation of vibrations of long suspension bridges. The control system is of the variable geometry type, where the wind flow around the oscillating bridge is controlled by flaps in a way, that the forces from the wind always opposes the velocity of the bridge section.

To investigate the principle to use flaps to control the vibrations of the bridge, wind tunnel experiments are planned with a bridge section model equipped with flaps. The experiments will take place in the wind tunnel for building aerodynamics at the Instituto Superior Technico in Lisbon, Portugal. The cross-section of the testsection is 1.5×1.5 m. and the wind velocity can be regulated in the interval 4–40 $^{\mathrm{m}}/_{\mathrm{s}}$.

The bridge section model is dimensioned to fit in the wind tunnel, whereby a practical usable model is dimensioned. The model is realistic compared to a real bridge, but no specific bridge is investigated. The bridge section model is designed so the length is 1.48 m and the flutter wind velocity is approximately 10 $^{\mathrm{m}}/_{\mathrm{s}}$. Characteristics for the 'prototype' and the model are shown below.

	'Prototype'	Model
Width B (excl. flaps) [m]	25	0.625
Mass per unit length m [kg/m]	25000	15.6
First eigenfrequency f_1 (bending) [Hz]	0.08	0.8
Second eigenfrequency f_2 (torsion) [Hz]	0.16	1.6

The bridge section model is made of foam with an aluminium frame. Where it has been possible there are holes in the aluminium frame to reduce the weight.

It is of interest to investigate flaps with different lengths. Therefore, flaps with lengths $0.15\,B$ and $0.25\,B$ are investigated, where B is the width of the model excl. flaps. The flaps can be regulated independently, they are able to rotate approximately 20° from the horizontal positions.

The model is connected to a horizontal extension rod in each side which is going through holes in the wind tunnel walls. The suspension system is the same in both sides. The extension rod is connected to an ams with dummy masses that can be moved on the arm so the model can represent the correct mass inertia. Each side of the arm is suspended in a spring. The suspension system is very flexible as it can be regulated in both horizontal and vertical directions.

The active control system consists of:

1. Sensors to measure the motion of the model. The displacements of the model are measured by using load cells connected to the ends of the springs.
2. Calculation of the optimal flap positions (closed-loop control). The methods used are: optimal control and neural network control.
3. Regulation system to position the flaps in the desired positions. This system consists of two seperate systems as the flaps can be regulated independently. Each system consists of a servo motor, reduction gear and servo amplifier. The systems are controlled by a software regulation program.

Theoretically, it is possible to use the flaps to change the magnitude and the direction of the forces from the wind and thereby increase the flutter wind velocity.